BNFL Inc.

Section 2.2

Ventilation Systems

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Ventilation Systems

2.2.1. Process Building Ventilation Systems

The main objective of the Process Building ventilation systems is to support the containment and confinement of sources of contamination, this principally by air flows and pressure differentials designed to promote air flow from areas of lesser contamination potential to areas of greater contamination potential.

2.2.1.1. Ventilation Systems

In order to meet the design objectives, it is envisaged that the following ventilation systems will be required (see Figure 2.2-1):

- C2 supply system
- C2 extract system
- C3 extract system
- C5 cave/cell extract system
- Vessel Ventilation extract system (Pretreatment Building)
- Combined Vessel Ventilation and Offgas extract system (LAW and HLW Building)

2.2.1.2. System Descriptions

2.2.1.2.1. C2 Supply System

The preferred configuration for the C2 supply system is 2 x 50% air handling units operating on 100% outside air (no recirculation). Unit fans will be connected to a normal electrical power supply with an alternate source. The system will provide filtration, heating, cooling and humidification either on the central air handling units or by the incorporation of zone heating coils, cooling coils, and in-duct humidifiers.

The system will be sized for the fresh air requirements within the occupied areas and to provide make-up air required for flows cascading into C3 and C4/C5 areas.

Instrumentation includes:

- radiation air monitor within air intake stream
- temperature measurement on both pre-heating and heating
- differential pressure across filter
- fan damper status and flow.

Trips are provided preventing the operation of C2 Supply fans if C2 Extract system is lost.

C2 Extract System

The C2 extract system central plant will comprise 2 x 50% duty extract fans. Each fan will be provided with manual isolating dampers on the fan inlet and pneumatic actuated isolating dampers on the fan outlet. Fans will be connected to a normal electrical power supply with an alternate source.

The air will be discharged via a dedicated local stack. The discharge air will be monitored for radiation prior to discharge.

The C2 Extract System will be sized to exhaust the air from the air supplied to C2 areas of the plant which is not cascaded to C3 areas.

Instrumentation includes radiation air monitors complete with alarms. If heat recovery is provided temperature measurement shall be provided up stream and down stream of equipment, differential pressure across fan, recovery equipment, and if provided, damper status. The C2 Extract System will shut down if either C5 or C3 extract fails.

Central Control Room/Incident Control Room/Emergency Ventilation System

The Central Control Room (CCR) and Incident Control Rooms (ICR) will be designed to permit occupancy and safe operation of the Facility during normal and upset conditions. During normal operations, the CCR/ICR will be ventilated from the C1/C2 supply and C1/C2 extract systems balanced to create a positive pressure to at least 1/8" wg relative to the surrounding areas. Fresh air make-up shall be provided at a rate of 10% of design volume. Heat gains generated within the CCR will be offset utilizing separate recirculating fan coil units.

On loss of normal operation of the ventilation systems, the CCR/ICR will be supported by an independent heated and filtered supply and extract system (Emergency Ventilation System) designed to maintain the CCR/ICR at a 1/8″ wg positive pressure relative to the adjoining areas. The C1/C2 supply and the C1/C2 extract systems that normally serve the CCR/ICR will be isolated from the Emergency Ventilation System(s) by means of isolating dampers. Consideration shall be given to the number and location of the supply air intake during detailed design. Fan systems shall be provided with duty and standby motors.

C3 Extract System

The C3 extract system central plant will comprise 2 x 100% fans, one operating as duty and one as standby. Fans will be connected to a normal electrical power supply with an alternate source. In the event of a duty fan failing, the standby fan will be automatically started. The fan motors will be provided with variable speed drives to provide adjustment of fan head to compensate for filter loading. Each fan will be provided with manual isolating dampers on the fan inlet and pneumatic actuated isolating dampers on the fan outlet.

Upstream of the fans will be a single stage of HEPA filters consisting of parallel banks of unshielded cabinet type manual safe change housings with a standby bank to allow on-line filter change.

The C3 extract system will be sized to exhaust the air from C3 area which is not cascaded to C4/C5 areas. Air cascading into the C5 areas via HEPA filters in the C2/C3 subchange room, or other C3 areas, will use high temperature, high capacity filter inserts within local, unshielded housings.

The discharge air will be ducted via a dedicated flue into the facility stack.

Instrumentation includes differential pressure monitors with alarms provided for high and low differential pressure across the filter arrangement and differential pressure indication for each bank.

Differential pressure monitors are provided across each fan, with alarms provided for low differential pressure. A low flow alarm is also provided downstream of the fans. Under normal operations a 'C3 Healthy' signal is sent to the C2 Extract system, which trips if this signal is lost.

C5 Extract System

The C5 extract system central plant will comprise 2 x 100% fans, 1 operating as duty and 1 as standby. Fans will be connected to a normal electrical power supply with an alternate source. In the event of a duty fan failing, the standby fan will be automatically started. The fans motors will be provided with variable speed drives to provide adjustment of fan head to compensate for filter loading. Each fan will be provided with manual isolating dampers on the fan inlet and pneumatic actuated isolating dampers on the fan outlet.

Upstream of the fans will be two stages of HEPA filters consisting of parallel banks configured in a duty standby arrangement to allow on-line filter change.

The initial results of the ALARA assessment for manual filter change will allow hands on safe change of filters for the pretreatment cells and the LAW vitrification caves. The filters for these areas, therefore, will consist of parallel banks of unshielded cabinet type manual safe change housings with a standby bank for on line filter change purposes.

For the HLW vitrification caves, initial results of the ALARA assessment for manual filter change will necessitate remote handling of the filters. The filters will therefore be housed within the HLW C5 cave area. The filters will be arranged in parallel banks with a standby bank for on-line filter changes.

The HLW vitrification caves will have access to the overhead cranes and power manipulator to facilitate filter changing. During filter change, the dirty filters are removed from housings and replaced by a clean filter. It is anticipated that clean filters will be placed in new cans and transferred into the breakdown cell via the bogie maintenance/bogie decontamination cave route. The dirty filters would typically be canned, lidded in cave, then placed in drums prior to posting out via the export route from the C5 cave area.

The discharge air will be ducted via a dedicated flue into the facility stack.

Instrumentation includes differential pressure monitors across each filter bank with alarms provided for high and low differential pressure. Differential pressure monitors are provided across each fan with alarms provided for low differential pressure. A low flow alarm is also provided downstream of the fans. Instrumentation is similar to that of the C3 Extract system with the addition of activity in air monitors installed between primary and secondary filters. The system provides a 'C5 Healthy' signal to the C3 Extract, which trips if this signal is lost.

2.2.1.2.2. Ventilation Control Philosophy

Control Modes

Control and monitoring of the ventilation systems will be primarily at the Central Control Room (CCR) or at local facility panels. The modes of control are as follows.

Normal Mode

This will range from full automatic operation of the facility, to individual sequences selected at the discretion of the operator, via a menu. Following initiation, operations will start and continue until a normal end condition or operator intervention occurs.

Normal modes of control would operate via the Integrated Control System (ICS).

Local Manual Mode

Local Manual mode will be available from the plant through local control stations/panels for the operation of plant and equipment. Individual items will be controlled within their normal limits of operation; e.g., motors started and stopped. Local Manual mode operations will be monitored in the CCR, where the status of operations performed can be displayed, although the items under control will not be accessible to the CCR for control simultaneously.

Remote Manual Mode

Remote manual mode will be available from the CCR to permit individual items to be controlled within their normal limits of operation; e.g. dampers opened and closed, fans started and stopped. Remote Manual mode will allow supervisor access during plant failure or following equipment repair, to allow the plant to be returned to a known datum condition prior to resuming Normal mode operations.

Recovery Mode

Recovery mode will be available as a means of operating individual items independently of the ICS from a local panel or Motor Control Centre (MCC). The Recovery mode will be used to make plant items safe or perform operational tests as a result of equipment repair or maintenance. Recovery mode will also be available in the event of ICS failure. A keyswitch will be used to select Recovery mode and so isolate the device from ICS control. Device control can then be performed via pushbuttons.

Recovery Mode will operate independently of the ICS.

Once plant and equipment is serviceable following Recovery actions, manual mode will be used to return the plant to a known datum condition prior to resuming Normal mode operations. In general, recovery mode will be used to make the plant safe.

Start Up

Following a system start-up, facilities will be required to allow entry of any initial or recovery information to enable operations to proceed. The system will default to this mode so the system can be placed in an initial state before permitting Normal mode operations to commence.

Shutdown

In Manual mode, shutdown facilities will be provided to allow a controlled halt of current operations such that the plant inventory is left intact.

In the event of the plant control system being unavailable (e.g., due to failure), an emergency shutdown system can be initiated by the operator through an independent system. The emergency shutdown system will be available at all times. In the event of loss of the CCR, initiation will be available from one or more Emergency Shutdown Panels within the facility.

2.2.1.2.3. Fan Start up and Shutdown Sequence

When starting the ventilation systems as part of an automatic startup sequence in the control system, the fans will be started in the following sequence to maintain the cascaded air flow:

1. Vessel Vent extract/Combined Vessel Vent and Offgas extract fans
2. C5 extract fans
3. C3 extract fans
4. C2 supply and extract fans.

For planned maintenance and shutdown, the ventilation systems will be taken out of service in the reverse of the starting order. During normal operation, if any system fails the shutdown sequence will be the sequence for removal from service. This sequence will be hardwired, however, and any systems having a higher contamination potential than the failed system will remain in operation.

2.2.1.3. Damper Operation

2.2.1.3.1. Fan Isolation Dampers

Isolation dampers on fan inlets will be manually operated with remote status indication and locked in the open position.

Isolation dampers on fan outlets will have pneumatic actuators and be automatically operated from the control system with remote status indication.

2.2.1.3.2. In-cell Filter Isolating Dampers

In-cell filter isolating dampers will be installed upstream and downstream of the filter banks to facilitate filter changing. Operation of the dampers will be performed remotely at the cell operating face using a manipulator.

2.2.1.3.3. Filter Isolating Dampers

Isolating dampers will be installed upstream and downstream of the out-cell filter banks to facilitate filter changing. The dampers will be manually operated with no remote status indication.

2.2.1.4. Discharges and Sampling/Monitoring

2.2.1.4.1. Discharges

<u>C2 Extract</u>

Air from C2 areas will be extracted, monitored and discharged to atmosphere via a dedicated local stack.

<u>C3, C5 Extract, Vessel Vent, Combined Vessel Vent and Offgas</u>

Air from the C3 and C4/C5 areas, pretreatment Vessel Vent, combined LAW Vessel Vent and Melter Off Gas systems, and HLW Vessel Vent and Melter Off Gas system will be filtered prior to discharge to atmosphere. Stack discharge sampling and monitoring would be provided on each system downstream of the fans. Each system will have a dedicated discharge duct from the building. It is envisaged that these individual flues will be routed from the building to the stack which will house the individual flues within a single wind shield.

2.2.1.5. Sampling/Monitoring

2.2.1.5.1. Duct Sampling

It is envisaged that the following systems will incorporate representative duct sampling and additional spare sample points for accountancy purposes:

- C2 supply upstream of the air handling units.
- C2 extract downstream of the fans
- C3 extract downstream of the fans
- C5 extract downstream of the fans
- Vessel Vent/Combined Vessel Vent and Offgas extract downstream of the fans

2.2.1.5.2. Continuous Monitoring

It is envisaged that the following air streams will incorporate continuous in-duct activity monitoring for radioactivity:

- C2 extract downstream of the fans
- C3 extract downstream of the fans
- C5 extract between primary and secondary filter stages.
- C5 extract downstream of the fans
- C5 Cave System downstream of the filters
- Vessel Vent extract between primary and secondary filter stages
- Vessel Vent extract downstream of the fans
- Combined Vessel Vent and Offgas extract between primary and secondary filter stages
- Combined Vessel Vent and offgas extract downstream of the fans

2.2.1.6. Filter Testing

HEPA filter inserts will be tested by the manufacturers and will have individual serial numbers and test certificates.

Filter efficiency testing will be performed for each filter bank when the filter elements are installed to verify that each filter element has not been damaged subsequent to leaving the manufacturers works and periodically as part of the maintenance activities to verify that the filter seals are functioning correctly.

The ductwork, dampers and filters, and the aerosol sample and injection points will be arranged to enable filter testing to be performed efficiently and reliably.

2.2.1.7. Fire Safety

The distribution ductwork will be routed throughout the building and will cross fire compartments boundaries and fire cladding of ductwork may be used for this purpose. The ductwork will be designed/routed, where possible, to minimize the need for fire dampers.

2.2.1.8. Seismic Qualification

Elements of the C5 extract system, vessel vent system, combined vessel vent and offgas system will require seismic qualification. Typically these elements would consist of the following:

- C5 system engineered inlet HEPA filter sets (filter housing, filter insert, ductwork and in-line equipment downstream of filter).

- C5 extract filter bank(s), including ductwork to C5 containment boundary interface.

- Vessel Vent extract primary filter bank/s including ductwork downstream to the C5 containment boundary interface.

- Combined Vessel Vent and Off gas extract primary filter bank(s), including ductwork downstream to the C5 containment boundary interface.

2.2.1.9. Hazardous Situations

The set of ITS SSCs for the ventilation system based on the identified hazards (or faults) is provided in Table 2.2-1 through Table 2.2-5.

The safety function of the selected ITS SSC is identified and the design safety feature, that give assurance that the SSC will perform its safety function, are provided.

Figure 2.2-1. Process Building Ventilation Flow Diagram

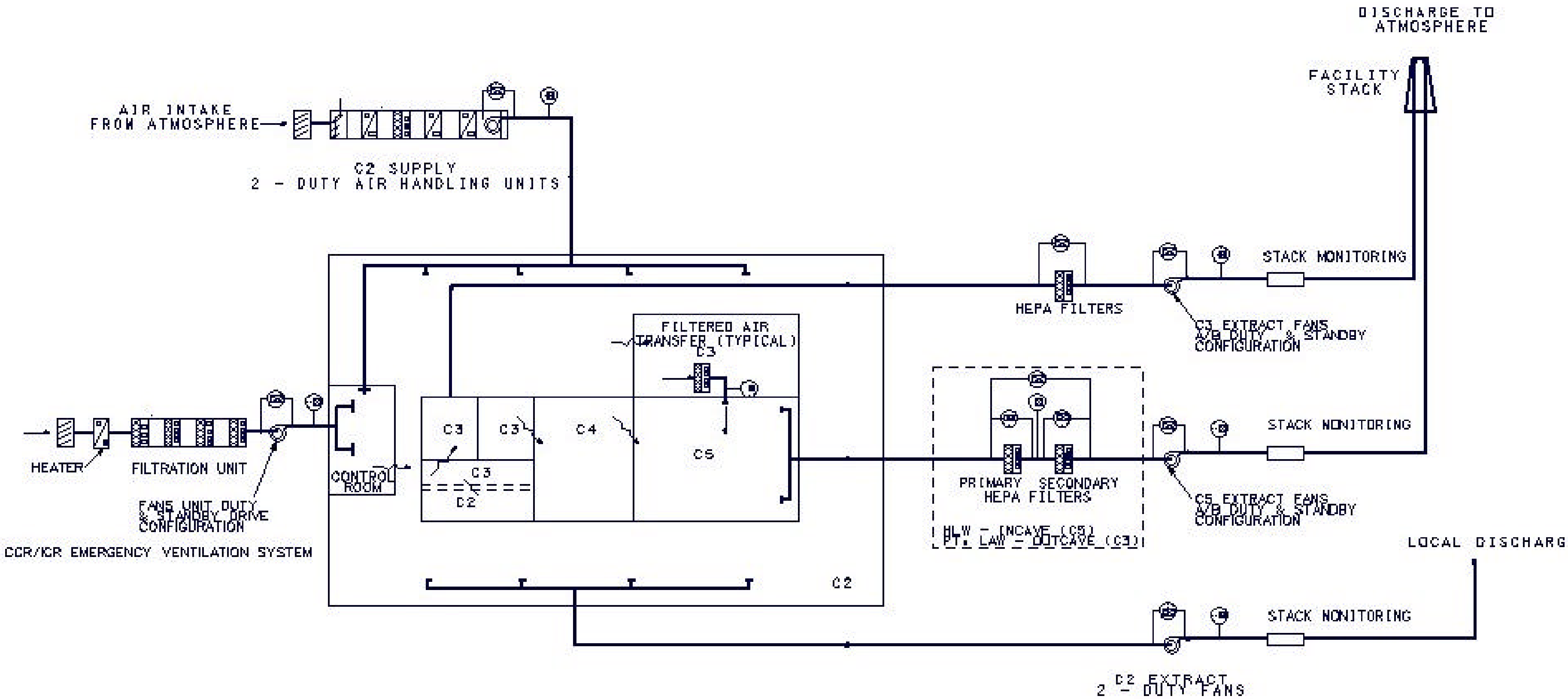

Table 2.2-1. Process Building Ventilation System – C2 Supply System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Continued operation of the C2 supply on loss of C2 extract system leading to the potential release of radioactivity to the environment through the building structure	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of C2 extract (stop C2 supply fan)	Overall system has diversity built in through the use of multiple inputs as shown below
	C2 extract low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	C2 extract low flow switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power or loss of input/output signal
	C2 extract fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	C2 extract damper closed proximity switch	Detect closure of C2 extract damper	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C2 supply fan on 2 from 3 fault signal from C2 extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal
Failure to isolate external and environmental inlet air on high radiation resulting in a potential hazardous atmosphere in the operating areas	Fresh air supply radiation monitor	Detect high radiation in inlet air	Trouble Alarm Battery Backed
	Central Control Room/Incident Control Room Alarm	Notify Operator	UPS Fail safe on loss of power or loss of input/output signal
	Isolation Damper	Isolates inlet supply system to limit the ingress of airborne contamination	Designed to withstand maximum depression of inlet/extract fan MOV with manual override Damper Indication

Table 2.2-2. Ventilation System – C2 Extract System

Fault	**Important to Safety SSCs**	**Safety Function**	**Design Safety Features**
Continued operation of C2 extract on loss of C3 extract system leading to the potential release of radioactivity from C3 or C2 areas	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of C3 extract (stop C2 extract fan)	Overall system has diversity built in through the use of multiple inputs
	C3 extract low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	C3 extract low flow switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power or loss of input/output signal
	C3 extract fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	C3 extract damper closed proximity switch	Detect closure of C3 extract damper	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C2 extract fan on 2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal

Table 2.2-3. Ventilation System – Central Control Room/Incident Control Room Emergency Ventilation

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of normal control room ventilation leading to the potential ingress of airborne radioactivity into the control room	Emergency ventilation system comprised of:	Provide positive pressure and fresh, clean, air makeup for operator safety	Periodic functional testing
	Fans	Maintain positive pressure and flow in ventilation system and control rooms	Multiple fans (2x100%) duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal -or- fan isolation damper closed
	HEPA Filter	Provide required decontamination factor	Passive Efficiency tested on installation
	Charcoal Filter	Provide chemical cleanup/removal	Passive
	Ductwork	Integrity boundary	Passive
	Heater	Humidity control to protect filter from excessive moisture	Multi-bank heaters
	Power supply for fans and heater	Support operation of the emergency ventilation system	Emergency electrical power
	Isolation Damper	Isolates emergency ventilation system from normal system	Fail safe (closed, spring) Air solenoids are fail safe Internal air reservoir with sufficient capacity for short term loss of compressed air (typically about 8 hrs) Manual override
	C1/C2 supply Cascade trip instrumentation	Initiate Emergency Ventilation System on loss of normal supply	Overall system has diversity built in through the use of multiple inputs as shown below
	C1/C2 supply low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	C1/C2 supply low flow switch	Provide input to shutdown sequence instrumentation	Fan low flow alarm Fail safe on loss of power or loss of input/output signal
	C1/C2 supply fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	C1/C2 supply damper closed proximity switch	Detect closure of C1/C2 supply damper	Fail safe on loss of power or loss of input/output signal

Table 2.2-3. Ventilation System – Central Control Room/Incident Control Room Emergency Ventilation

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Logic circuitry	Start emergency ventilation system on 2 from 3 fault signal from C1/C2 supply fan low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) –or- damper closed signal Fail safe on loss of power or loss of input/output signal

Table 2.2-4. Ventilation System – C3 Extract System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Fan failure leading to the potential migration of airborne radioactivity from the C3 to C2 areas	Fans	Maintain negative pressure and flow in system	Multiple fans (2x100%) duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal -or- fan isolation damper closed Procedural controls for duty sharing
	Power supply for fans	Supply power to fans	Emergency electrical power
	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of C3 extract fans	Overall system has diversity built in through the use of multiple inputs as shown below
	C3 extract low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	C3 extract low flow switch	Provide input to shutdown sequence instrumentation	Fan low flow alarm Fail safe on loss of power or loss of input/output signal
	C3 extract fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	C3 extract damper closed proximity switch	Detect closure of C2 extract damper	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C2 extract fan on 2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal
Mis-set dampers in system leading to the potential to contaminate workers during fan maintenance or loss of cascade ventilation principle and potential migration of radioactivity from areas of higher contamination to areas of lower contamination	Dampers	Automatically isolate failed fan on standby start	Fail safe (closed, spring) Air solenoids are fail safe Internal air reservoir with sufficient capacity for short term loss of compressed air (typically about 8 hrs) Manual override

Table 2.2-4. Ventilation System – C3 Extract System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
HEPA failure due to blockage results in loss of cascade ventilation principle and potential migration of radioactivity from areas of higher contamination to areas of lower contamination	HEPA filters	Provide required decontamination factor (DF) to below discharge limits	Filters banked with sufficient capacity such that spare filter is available for online filter change purposes (not redundant capacity) Procedural controls to change filter train based on predetermined operating parameters (e.g. pressure, time, activity)
	HEPA filter differential pressure instrument switch	Provide local differential pressure indication	Simple static device Procedural controls to change filters at predetermined delta pressure value
HEPA failure – Due to incorrect installation on changeout or filter breach resulting in releases in excess of allowable limits	Radiation monitor downstream of filters	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor CCR/ICR alarm	Notify operator to initiate shutdown sequence	UPS Fail safe on loss of power, loss of input/output signal
	Isolation damper	Isolate exhaust stream	Motor operated with manual override Position indication
	HEPA filter differential pressure instrument switch	Provide indication of incorrectly installed or breached filter	Simple static device Procedural controls to troubleshoot filter on low differential pressure
	Efficiency test points	Allow testing to confirm efficiency of installed filters	Test locations are within C3 ventilated areas (any leakage will return to C3 ventilation system) Test connections have double isolation when not in use

Table 2.2-5. Ventilation System – C5 Extract System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Fan failure resulting in loss of cascade ventilation principle and potential migration of radioactivity from areas of higher contamination to areas of lower contamination	Fans	Maintain negative pressure and flow in system	Multiple fans (2x100%) duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal -or- fan isolation damper closed Procedural controls for duty sharing
	Power supply for fans	Supply power to fans	Emergency electrical power
	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of C5 extract fans	Overall system has diversity built in through the use of multiple inputs as shown below
	C5 extract low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	C5 extract low flow switch	Provide input to shutdown sequence instrumentation	Fan low flow alarm Fail safe on loss of power or loss of input/output signal
	C5 extract fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	C5 extract damper closed proximity switch	Detect closure of C5 extract damper	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C3 extract fan on 2 from 3 fault signal from C5 extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal
Mis-set dampers in system leading to the potential to contaminate workers during fan maintenance or loss of cascade ventilation principle and potential migration of radioactivity from areas of higher contamination to areas of lower contamination	Damper	Automatically isolate failed fan on standby start	Fail safe (closed, spring) Air solenoids are fail safe Internal air reservoir with sufficient capacity for short term loss of compressed air (typically about 8 hrs) Manual override

Table 2.2-5. Ventilation System – C5 Extract System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
HEPA failure due to blockage results in loss of cascade ventilation principle and potential migration of radioactivity from areas of higher contamination to areas of lower contamination	HEPA filters	Provide required decontamination factor (DF) to below discharge limits	Filter banks with sufficient capacity such that spare filter is available for online filter change purposes (not redundant capacity) Procedural controls to change filter train based on predetermined operating parameters (e.g. pressure, time, activity)
	HEPA filter differential pressure instrument switch	Provide local differential pressure indication	Simple static device Procedural controls to change filters at predetermined delta pressure value
HEPA failure – Due to incorrect installation on changeout or filter breach resulting in releases in excess of allowable limits	Radiation monitor downstream of filters	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor CCR/ICR alarm	Notify operator to initiate shutdown sequence	UPS Fail safe on loss of power, loss of input/output signal
	Isolation damper	Isolate exhaust stream	Motor operated with manual override Position indication
	HEPA filter differential pressure instrument	Provide indication of incorrectly installed or breached filter	Simple static device Procedural controls to troubleshoot filter on low differential pressure
	Efficiency test points	Allow testing to confirm efficiency of installed filters	Test locations are within C3 ventilated areas (any leakage will return to C3 ventilation system) Test connections have double isolation when not in use
Blockage of HEPA filtered flowpath (i.e., backflow filter) from cell to operating area compromising the passive vent capability for the prevention of hydrogen buildup or cell cooling.	Cell ducting	Provide cell vent path	Passive Seismically qualified Multiple flow paths for each cell Isolation damper locked open
	HEPA filter	Provide cell vent path	Seismically qualified Low resistance filter design Passive Flow indication/alarm to detect filter blockage

Table 2.2-5. Ventilation System – C5 Extract System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Failure or degradation of HEPA filter (i.e., backflow filter) in flowpath from cell to operating area resulting in potential migration of activity from cell to operating area on loss of cell depressurization	HEPA filter	Provide required decontamination factor to inhibit migration of activity from cell to operating area on loss of cell depressurization (loss of C5 Extract System)	Passive Filters are efficiency tested when installed and following any maintenance or changeout
	Efficiency test points	Allow testing to confirm efficiency of installed filters	Test locations are within C2/C3 ventilated areas (any leakage will return to C2/C3 ventilation system) Test connections have double isolation when not in use

2.2.2. Pretreatment Vessel Vent System

2.2.2.1. Purpose

The pretreatment vessel ventilation system is provided to control the atmosphere in process vessels and plant equipment. The ventilation requirements for a vessel will vary depending on its operating frequency and characteristics. In particular, the vessel filling and emptying rates, the number of pneumercators, the number and size of fluidic pumps, other liquid transfer devices, agitation, temperature changes, chemical reactions, emergency conditions, etc. will affect the vessel ventilation requirements. When all the individual requirements are known, ventilation schemes can be produced covering compatible vessels and an overall vessel vent header collection system detailed. It is normal to size the vent lines based on normal and maintenance flows only and ignore emergency conditions.

2.2.2.2. Description

The sub-headers are located above the equipment being vented to avoid the risk of siphoning. This venting is particularly important where no vessel overflows are installed. For operational reasons, the headers are oversized so that vessel pressures throughout the plant are approximately equal. The oversizing should also prevent contamination of other vessels should an overflow to the vent header occur. The vessel vent connections to the sub-headers are by “U” bends to the top and the slope of the headers should preferably be 1 in 20, but as a minimum 1 in 40. The order of connection of vessels to the sub-headers should be progressively from the least active to the most active nearest the treatment system.

In the vicinity of the vessel vent treatment equipment, the sub-headers are collected in a vertical header section which is provided with a drain to a suitable collection vessel. The collection vessel will also need venting to the top of the system near the point of entry to the treatment equipment.

The Pretreatment Vessel Vent System receives offgas streams from the exhausts of reverse flow diverters, pulse jet mixer, and process vessel vents. The system maintains a negative pressure to ensure flow into the system from the C5 ventilated areas.

A combined reverse flow diverter exhaust, pulse jet mixer exhaust, and process vessel vent stream is passed through one of two HEMEs to remove entrained droplets and particulate. The HEMEs work on a duty-standby basis and each HEME has inlet and outlet sealpots to allow isolation for maintenance and replacement purposes. The HEMEs require routine washing to remove the buildup of particulates.

The combined vent stream then is passed through a counter-current scrubbing column to perform a final cleanup of the offgas and to cool the offgas stream. The scrubbing column is a packed column with an integral sump to collect scrubber liquids. The sump cooling coils are supplied with chilled water. Liquid is recirculated to the top of the scrubbing column. Fresh makeup water is added to the top of the column and the sump tank overflows to a collection vessel. Wastewater from the collection tank, which includes the HEME washings, is sent to the plant drainage system.

Offgas exiting the scrubbing column passes through a heater where the gases are heated above their dewpoint to prevent condensation in the downstream high efficiency particulate air (HEPA) filters. The heater is electrically powered with spare elements installed to provide redundancy. After heating, the offgas passes through primary and secondary HEPA filters. Filters consist of parallel banks of unshielded, single canister type, manual safe change housings with a single standby housing for on-line filter change purposes.

The vessel vent extract system comprises 2x100% duty/standby exhaust fans that will be connected to a normal electrical power supply with an alternate source. In the event of a duty fan failing, the standby fan will be automatically started. The fan motors will be provided with variable speed drives to provide adjustment of fan head to compensate for filter loading. Each fan will be provided with manual isolating dampers on the fan inlet and pneumatic actuated isolating dampers on the fan outlet.

The discharge air will be ducted via a dedicated flue into the pretreatment facility stack.

Instrumentation provided for the final offgas stream includes differential pressure monitors across each filter bank with alarms provided for high and low differential pressure. Differential pressure monitors are provided across each fan with alarms provided for low differential pressure. A low flow alarm is also provided downstream of the fans. Instrumentation is similar to that of the C3 extract system with the addition of activity in air monitors installed between primary and secondary filters. The system provides a “not failed” signal to the C5 extract system. Tripping of the C5 extract on vessel vent system failure will be considered during detailed design development. A schematic of the pretreatment vessel ventilation system is provided in Figure 2.2-2.

2.2.2.3. Hazardous Situations

Loss of flow/depression could result in migration of gases or aerosols from an area of higher contamination potential (vessels) to areas of lower contamination potential (C5 areas). A decrease in the system treatment capability would result in increased activity levels and the potential for releases that exceed allowable limits. Faults associated with these hazardous situations are:

- Fan failure resulting in loss of cascade ventilation principle.
- Faults that result in a blockage of the vessel ventilation system
- Faults that reduce scrubber efficiency
- Heater failure (increased moisture and subsequent HEPA blockage)
- HEPA filter failure or malfunction (bypass)

The set of ITS SSCs based on the above hazardous situations is provided in Table 2.2-6. The safety function and design safety features are provided for each SSC.

Figure 2.2-2. Pretreatment Vessel Ventilation System

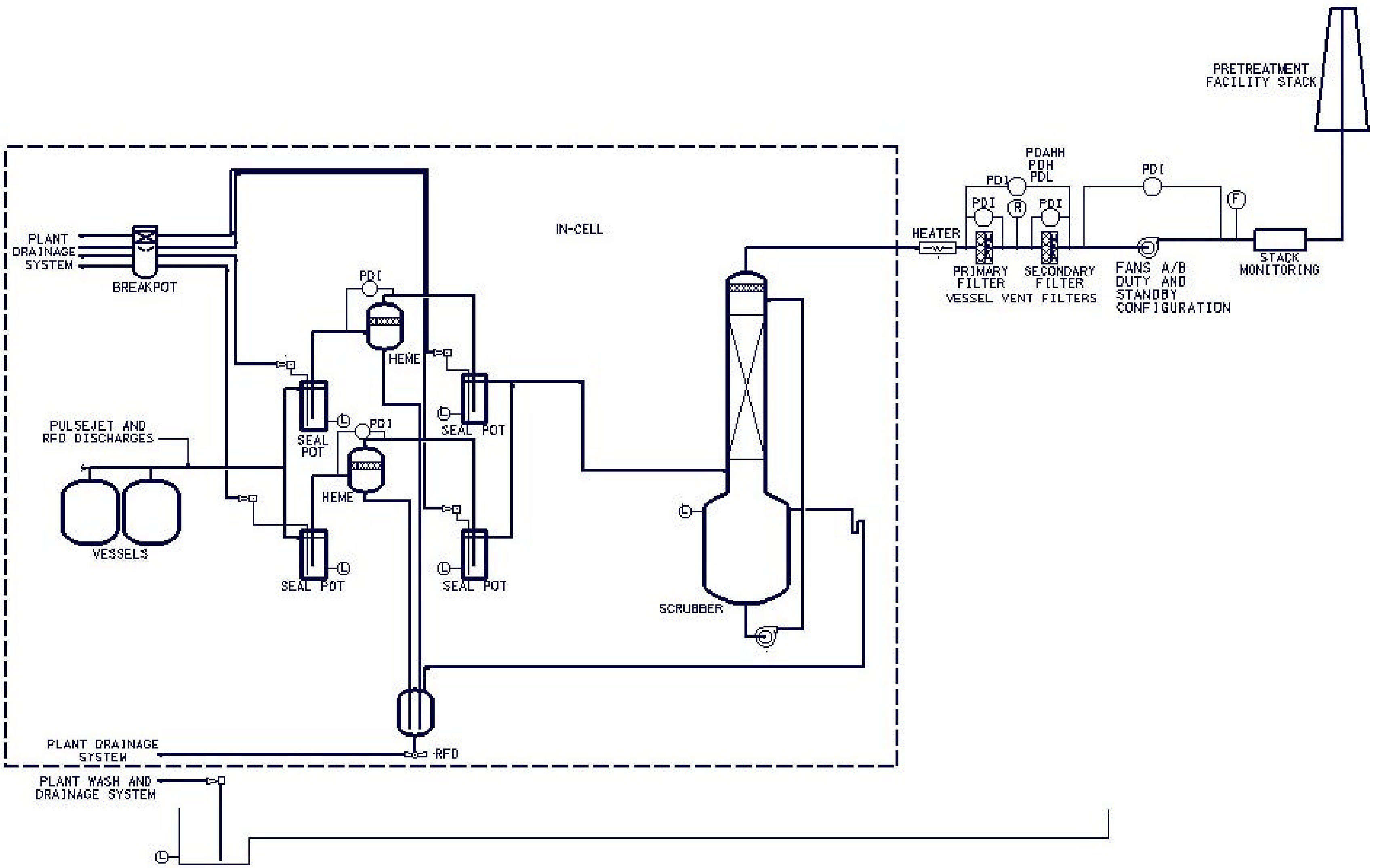

Table 2.2-6. Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Fan failure resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Fans	Maintain negative pressure and flow in system	Multiple fans (2x100%) duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal -or- fan isolation damper closed Procedural controls for duty sharing
	Power supply for fans	Supply power to fans	Emergency electrical power
	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of Vessel vent extract fans	Overall system has diversity built in through the use of multiple inputs as shown below
	Low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	Low fan flow switch	Provide input to shutdown sequence instrumentation	Fan low flow alarm Fail safe on loss of power or loss of input/output signal
	Fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	Fan damper closed proximity switch	Detect closure damper Provide input to standby fan auto start logic	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C5 extract fan on 2 from 3 fault signal from vessel vent extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal

Table 2.2-6 Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Incorrect seal pot water level (inadvertent isolation) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity to areas of lower contamination	Level instrumentation	Alert operator of incorrect level in seal pot	Trouble Alarm Alarm on high level
	Seal Pot	Maintain ventilation flowpath	Seal pot depth to be sufficient to cater for water build up through condensation. Causing the sealing of the vent line
HEME blockage due to high humidity	HEME pressure differential instrumentation	Reveals HEME blockage	Alarm on Differential Pressure Trouble Alarm
Heater failure (blockage of HEPA) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Heater	Control humidity	Redundant heaters
	Power supply to heater (supporting service)	Provide power to heater	Emergency electrical power
	Temperature indication and alarm instrumentation	Reveal heater failure (indication/alarm)	Fail safe on loss of power, loss of input/output signal UPS

Table 2.2-6 Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Scrubber flooding (blockage) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Overflow line	Prevent level from obstructing air flow path	Passive system tested during commissioning Overflow line sized to maximum makeup
Mis-set dampers in system leading to the potential to contaminate workers during fan maintenance or loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Dampers	Automatically isolate failed fan on standby start Not isolate duty fan during normal operation	Fail safe (closed, spring) Air solenoids are fail safe Internal air reservoir with sufficient capacity for short term loss of compressed air (typically about 8 hrs) Manual override

Table 2.2-6. Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
HEPA failure due to high differential pressure resulting in releases of airborne radioactivity exceeding allowable limits	HEPA filters	Provide required decontamination factor (DF) below discharge limits	Filters banked with sufficient capacity such that spare filter is available for online filter change purposes (not redundant capacity) Procedural controls to change filter train based on predetermined operating parameters (e.g. pressure, time, activity)
	HEPA filter differential pressure instrument	Provide local differential pressure indication	Simple static device Procedural controls to change filters at predetermined delta pressure value
HEPA failure due to heater failure (fire or loss of humidity control) resulting in releases of airborne radioactivity in excess of allowable limits	HEPA filter material	Maintain integrity in the event of a heater malfunction	Glass paper HEPA Filter coated to withstand high water loading Passive feature (sufficient distance between heater and HEPA to preclude heat/fire damage)
HEPA failure – Due to incorrect installation on changeout or filter breach resulting in releases in excess of allowable limits	Radiation monitor downstream of filters	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor downstream of both filter stages	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor CCR/ICR alarm	Notify operator to initiate shutdown sequence	UPS Fail safe on loss of power, loss of input/output signal

Table 2.2-6. Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Isolation damper	Isolate exhaust stream	Motor operated with manual override Position indication
	HEPA filter differential pressure instrument	Provide indication of incorrectly installed or breached filter	Simple static device Procedural controls to troubleshoot filter on low differential pressure
	Efficiency test points	Allow testing to confirm efficiency of installed filters	Test locations are within C3 ventilated areas (any leakage will return to C3 ventilation system) Test connections have double isolation when not in use.
Loss of confinement due to radiolytic hydrogen explosion.	Vessel ventilation system	Reliably keep the H_2 concentration in the tank vapor space and the cell below the LFL during normal operations Provide confinement flow	Designed to keep the H_2 concentration $\leq$ 1 vol% Designed to maintain confinement airflow through vessel openings. See DSFs for individual components above ensuring reliable operation of the Vessel Ventilation System under fault conditions
	Ducting	Provide reliable flow path from vessel vapor space to building exhaust	Maintain confinement boundary
	Flow control and abatement devices	Direct flow from the vessel vapor space to the environment	Redundant flow paths or bypass paths provided for active components subject to isolation or blocking. Automatic realignment on fan switchgear
	Vessel inlets	Provide flow path from cell to vessel vapor space	Sized to ensure adequate dilution of hydrogen in vessel vapor space

Table 2.2-6 Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Passive Vessel Ventilation System	Mixes the atmospheres in the vessel vapor space with the cell atmosphere to maintain H_2 concentrations in the vapor space and the cell below the LFL Maintain functionality during and following an earthquake	Passive system Seismically qualified
	Vessel Inlets	Provide flow path between the vapor space and the cell	Seismically qualified Sized not to block even if both the vessel level controls and the overflow line fail to prevent an overflow
	Chimney	Provide flow path between the vapor space and the cell	Seismically qualified
	Vessel	Support passive vessel vent path	Seismically qualified No moving parts No electrical connections
	In-cell components	Do not interfere with vessel vent path	Seismically qualified as required to protect the passive vessel vent No electrical components in cell
	Cell vent path elements	Provide flow path from the cell to the operating gallery	Passive system Seismically qualified
	Cell Ducting	Provide cell vent path	Seismically qualified
	Inlet damper	Provide cell vent path	Seismically qualified
	Backflow filter	Provide cell vent path	Seismically qualified Low resistance filter design
	Out of cell components	Do not interfere with cell vent path	Seismically qualified as required to protect the cell vent path
	Cell	Assure cell vent path	Seismically qualified
	Above cell structure	Assure cell vent path	Seismically qualified as required to protect the cell vent path

Table 2.2-6 Ventilation System – Pretreatment Vessel Vent System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
	Air purge system	To keep the hydrogen concentration in the vapor space below LFL	Injection rates to be sufficient to guarantee hydrogen concentration is <1 vol% Supply to be available post seismic event
	Purge supply pipework	To carry air purge	To be available, or readily restorable, from air supply point to vessel post seismic event. Multiple entry points for each vessel with additional injection points for dead legs in pipework system
	Flow measurement instrument switch	To reveal low flow and initiate switchover to bottle back system To alert operators	Duplicate measurement with pressure Low flow alarm Fail safe on loss of power or loss of input/output signal
	Pressure measurement instrument switch	To reveal low pressure and initiate switchover to bottle back system To alert operators	Duplicate measurement with flow Low pressure alarm Fail safe on loss of power or loss of input/output signal
	Instrument Air System	To supply purge air	See Instrument Air System under Services and Utilities for the DSFs of the Instrument Air System. In addition a dedicated HP compressor for bottle filling will be available
	Power supply	To operate compressors and instruments	Emergency Power
	Bottle back air supply	To provide purge air supply for the duration of the maximum credible compressor outage	Bottles are multiple and provide redundancy. They are valved to allow refilling from any compressed air supply whilst maintaining purge duty. Bottles can be taken to a compressed air supply if installed supply becomes unavailable
	Automatic changeover units	To changeover to bottle back system on detection of low flow or low pressure	Operators are required to confirm changeover has occurred and to initiate it manually if it has not occurred on receipt of low flow or pressure alarms

2.2.3. LAW/HLW Melter Offgas and Vessel Vent System

2.2.3.1. Purpose

The purpose of the vessel ventilation and HLW/LAW melter offgas treatment systems is to process the offgas to prevent discharges to the atmosphere that could exceed environmental discharge limits. The systems treat the gas streams to remove potentially radioactive entrained aerosols and small particulate, and to decrease the acid gas content.

2.2.3.2. Description

The LAW/HLW melter offgas and vessel ventilation systems maintain an adequate pressure in the melter and active vessels relative to the cells to insure flow from areas of lower contamination potential (C5 system) towards areas of higher contamination potential (active vessels and melter).

For the LAW/HLW treatment process, various items of process equipment require ventilation as part of the vessel ventilation system. In addition, the LAW/HLW melters will have an offgas system which will require treatment before discharge to the atmosphere.

The offgas from the melters is initially treated before being combined with the vessel ventilation system for further treatment before discharge to the atmosphere. These primary and secondary offgas systems are discussed in the following sections.

2.2.3.2.1. LAW and HLW Melter Offgas Systems

In the LAW and HLW melters, water is evaporated from the feed and released to the offgas system as superheated steam. The feed components then undergo chemical reaction and decomposition. During the decomposition process, gases are formed and released into the melter plenum and offgas system. In addition, a fraction of the feed components are is entrained in the melter offgas. The solids and semi-volatile components are recycled back to the process upstream of the melter.

Each LAW and HLW melter is provided with a dedicated film cooler and quencher. The gas streams from the melters include steam, air from bubblers, acid gases (e.g., $NO_{x,}$ HCl, and HF), and entrained feed components. These gases and particulates pass through a film cooler that cools the gas by direct injection of air. A quench/scrubber is provided to remove entrained particulate.

In addition to particulate, the quencher/scrubber recovers a high percentage of the HCl and HF gases released from the melter. To minimize the concentration (and hence corrosion rate) of the acids retained in the scrubber liquor, demineralized water is added to the quencher sump. The sump contents are periodically recycled back to the process upstream of the melter, which increases the incorporation rate for these components in the glass.

2.2.3.2.2. LAW Melter Primary Offgas System

The LAW melter primary offgas system consists of high-efficiency mist eliminators (HEME), a selective catalytic reduction (SCR) unit, heat exchangers, and a condenser. Figure 2.2-3

A pair of HEMEs is provided for each LAW melter. One HEME is in operation while the second unit is in standby mode or is being washed. The HEMEs remove approximately 99% of the radioactivity content from the offgas stream that is in the form of liquid aerosols. The offgas stream exiting the HEME for each LAW melter are combined prior to entering the SCR. When the pressure drop across a HEME reaches a pre-determined level, the unit is taken off-line and the standby unit brought into service. The HEME is backwashed with process water to recover its pressure drop. The liquids from operation and washing of the HEME are collected in a sump and recycled back to the process upstream of the melter.

The SCR unit converts the NO_x in the gas stream into nitrogen and water vapor by reaction with ammonia in the presence of an alumina catalyst impregnated with metal oxide. After leaving the SCR, the offgas is passed through two separate heat exchangers. The first heat exchanger cools the gas stream exiting the SCR by heat exchange with the pre-heated offgas feed. Air is added after this heat exchanger to dilute the concentration of NO_x in the gas stream. The diluted offgas then is raised to reaction temperature in a second heat exchanger.

The gas stream exiting the SCR heat exchanger is further cooled in the LAW offgas condenser. This unit condenses water vapor and significantly reduces the level of radioactivity in the offgas by removing tritium from the offgas as tritiated water. The liquid stream from the condenser is collected and combined with other offgas liquid effluents in the shared active condensate tanks for subsequent transfer to the central effluent handling area of the TWRS-P facility. The condenser offgas is further treated in the LAW secondary offgas system (see Section 2.2.3.2.5).

2.2.3.2.3. HLW Melter Primary Offgas System

The HLW primary offgas system consists of a HEME, a high-efficiency metal filter (HEMF), an iodine adsorption unit, a condenser, and a wet scrubber. Figure 2.2-4 The function of the HEME is the same as for the LAW system. However, the 99% efficiency of the HEME is not sufficient for the HLW offgas and the offgas is passed through a HEMF, which is capable of achieving a much higher efficiency of particulate removal than the HEME. The offgas exiting the HEME is heated well above its dew-point to prevent condensation and then passed through the HEMF. The liquids resulting from HEME operation, and from washing of the HEME and the HEMF, collect in a sump and are recycled back to the process.

There is potential for iodine-129 to be present in the HLW offgas based upon the HLW feed specifications. Because iodine exists as a gas, it is not removed by either the HEME or the HEMF. A dry adsorption unit is used to remove 98% or more of the iodine gas (estimated in the feed). The sorbent bed of the unit, either silver nitrate-impregnated silica gel or silver exchange zeolite, is disposed of as solid waste.

Following iodine adsorption, the HLW offgas stream is treated in the HLW Offgas Condenser, which removes radioactivity (including tritium) and acid gases from the offgas by condensing water vapor. The condensate is collected and combined with other offgas liquid effluents for transfer to the TWRS-P central effluent handling area. The offgas is further treated in the HLW offgas caustic scrubber to remove acid gases and carbon-14. The HLW offgas stream is finally treated in the HLW secondary offgas system.

2.2.3.2.4. LAW and HLW Vessel Vent Systems (Refer to Pretreatment Vessel Vent System for Design Safety Features)

The vessel ventilation system provided for the LAW and HLW facilities is similar to the Pretreatment Vessel Ventilation System, as discussed in Section 2.2.2.

The LAW/HLW vessel vent system receives offgas streams from reverse flow diverters exhaust, pulse jet mixers, and the process vessel vent. The combined stream passes through one of two HEMEs to remove entrained droplets and particulate. The HEMEs work on a duty standby basis and each HEME has an inlet and outlet seal pot to allow isolation for maintenance and replacement purposes. The HEMEs require routine washing to remove the buildup of particulates. The effluent generated from the washing operation is recycled back to the process upstream of the melter.

2.2.3.2.5. LAW and HLW Melter Secondary Offgas Systems

The melter offgas and vessel vent streams are combined and treated in a secondary offgas system which consists of a scrubber, heater, and two stages of HEPA filters. The combined gas stream is scrubbed, then heated to above its dew-point to prevent condensation within downstream high efficiency particulate filters. The heater is electrically powered with spare elements installed to provide redundancy. After heating, the offgas passes through primary and secondary HEPA filters and then through one of two exhaust fans before discharge to atmosphere. Filters consist of parallel banks of unshielded, single canister type, manual safe change housings with a single standby housing for on-line filter change purposes.

The vessel vent extract system comprises 2x100% duty/standby fans that will be connected to a normal electrical power supply with an alternate source. In the event of a duty fan failing, the standby fan will be automatically started. The fan motors will be provided with variable speed drives to provide adjustment of fan head to compensate for filter loading. Each fan will be provided with manual isolating dampers on the fan inlet and pneumatic actuated isolating dampers on the fan outlet.

Consideration will be given during detailed design to providing Vessel Vent fan motors powered from a battery backed electrical supply. This capability reduces the potential for total loss of ventilation systems on cascade trips and reduce the potential for plant evacuation and melter shutdown.

The discharge air will be ducted via a dedicated flue into the facility stack.

Instrumentation on the final offgas stream includes differential pressure monitors across each filter bank with alarms provided for high and low differential pressure. Differential pressure monitors are provided across each fan with alarms provided for low differential pressure. A low flow alarm is also provided downstream of the fans. Instrumentation is similar to that of the C3 extract system with the addition of activity in air monitors installed between primary and secondary filters. The system provides a “not failed” signal to the C5 extract system. Tripping of the C5 extract on vessel vent system failure will be considered during detailed design development

2.2.3.2.6. LAW and HLW Melter Standby Offgas Systems

The LAW and HLW melter standby offgas systems are designed to be used infrequently. The primary and secondary offgas ducting for the LAW melters is designed for 1.4 times normal sustained throughput and the HLW melter is designed for 1.9 times normal sustained throughput. In addition, both the HLW and LAW offgas systems are designed to accommodate 7 times normal condensable and 3 times normal non-condensable flows due to surges in the melter causing a reduction in melter vacuum. If the vacuum in a melter is reduced below a predetermined value, its feed is stopped, which normally prevents a further loss of vacuum. The standby offgas system for a melter is only activated to protect the melter from becoming pressurized.

Each LAW and HLW melter has one standby offgas line. The standby offgas systems for each type of melter are of the same basic design. Ducts connect the melters to isolation dampers, one for each melter. These dampers isolate the melters from the standby offgas lines during normal operation. The dampers are automatically activated by pressure sensors in the melter. Immediately downstream of the dampers, air is injected into the gas streams. The air volume is regulated to limit the temperature of the diluted stream. This cools the gas stream to below the softening point of the entrained glass particulate, to protect downstream equipment.

Each diluted gas streams passes through to a high-efficiency cartridge filter of fine fibers or ceramic. Deposited solids are removed from the filter by backblowing with compressed air after or during use. The pressure drop across the filter is continuously measured during operation to check that the filter is not clogging. If the pressure drop becomes too high, the cartridge is washed. If the pressure drop cannot be recovered by washing, the cartridge is replaced.

Particles removed from the filter by backblowing fall down into the base of the vessel, where they are washed out and gravity drain to a sump vessel that is common to all gas streams for a particular melter type. The sump level is monitored, and when it is full the liquid is emptied by a fluidic pump to the contaminated condensate tank in the central effluent handling area of the facility. After washing, the filters are dried. Glass particles collected in the sump are recycled to the process upstream of the melter.

The pressure drop across the standby offgas lines is less than across the corresponding main line. To avoid excessively low pressure in the melter, the streams pass through vortex amplifiers that are supplied with process air at varying rates. The vortex amplifier is highly reliable fluidics device (no moving parts) used in BNFL nuclear facilities. The operation is based on the Coriolis effect. The air rates control the pressure drops. These air rates allow the system to stabilize after the pressure surge. A vortex amplifier is used to maintain the melter pressure at the desired level until the melter system can be removed from the emergency offgas system. At this point, the isolation damper is closed, and the main offgas system is used again.

After filtration, the streams for a particular melter type combine and rejoin the melters primary offgas treatment system. The LAW stream rejoins the primary stream at the inlet to the LAW offgas condenser and the HLW stream rejoins the main stream at the inlet to the iodine-removal column. Removal of oxides of nitrogen (LAW only) and acid gas takes place downstream in the offgas train.

2.2.3.3. Hazardous Situations

Operation of the melter offgas system is necessary to maintain a negative pressure in the melter relative the surrounding C5 area to maintain the cascade ventilation philosophy. Faults that disable or degrade the flow through this system would result in increased activity in the C5 area and would present a challenge to the C5 ventilation system. The offgas system also contains and treats the gas stream to maintain toxic and radioactive releases within prescribed limits. Faults that degrade the systems capability to treat the waste stream could result in releases that exceed the allowable release limits. Faults associated with these hazardous situations are:

- Loss of film cooler cooling due to glass buildup and subsequent blockage
- Loss of or degraded quencher function (degraded treatment). The current expectation is that the demineralized water supply system for the quencher is not an ITS SSC because of the holdup of liquid in the quench reservoir.

- Faults that result in system blockage and loss of flow

- Pressure surges in the system that could damage components or breach the system

Low temperature in the LAW SCR could result in the formation of ammonium nitrate that is highly volatile. High temperature or loss of ammonia feed could result in the reformation of NO_x downstream of the SCR and result in releases that exceed allowable limits. Faults associated with these hazardous situations are:

- Incorrect temperature of the SCR unit
- Loss of ammonia supply

The set of ITS SSCs based on the above hazardous situations is provided in Table 2.2-7 through Table 2.2-9. The safety function and design safety features are provided for each SSC.

Figure 2.2-3. LAW Melter Offgas and Vessel Ventilation Systems

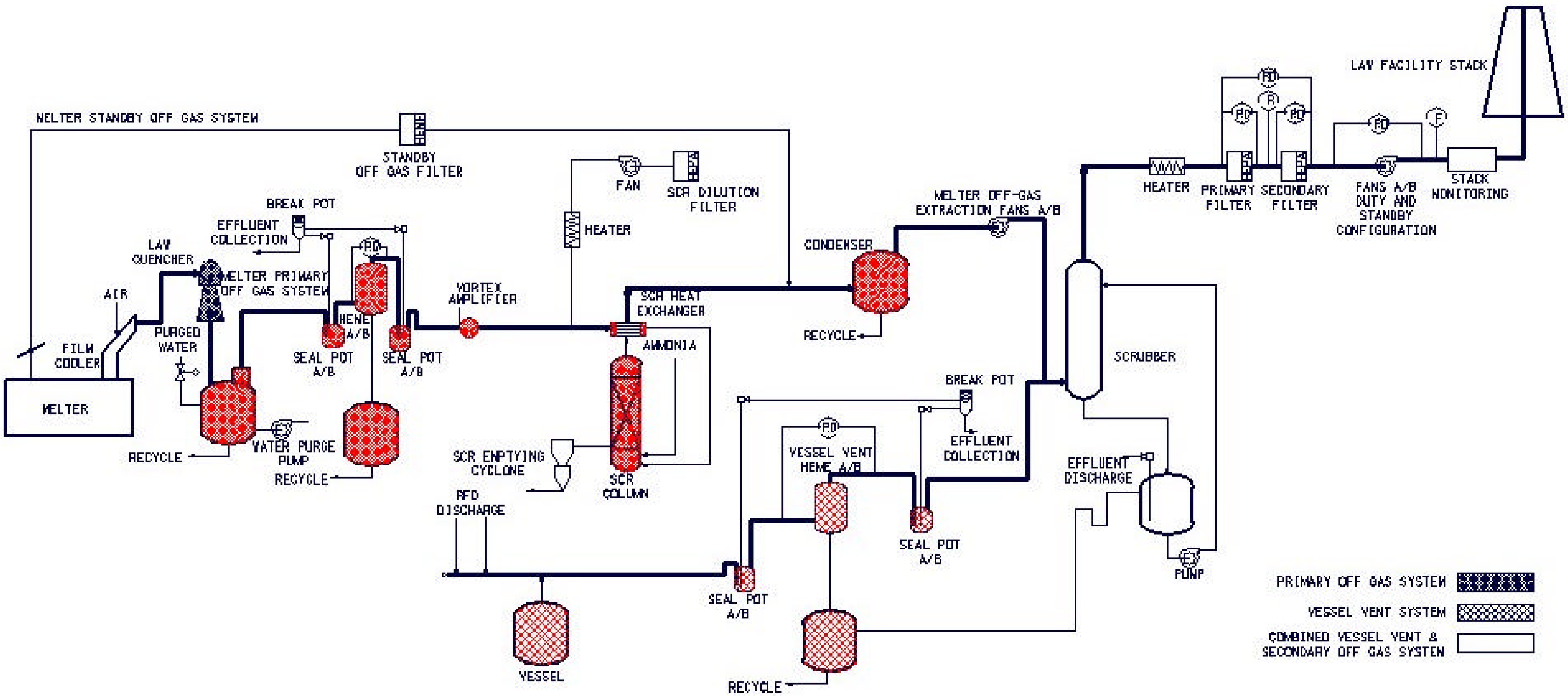

Figure 2.2-4. HLW Melter Offgas and Vessel Ventilation Systems

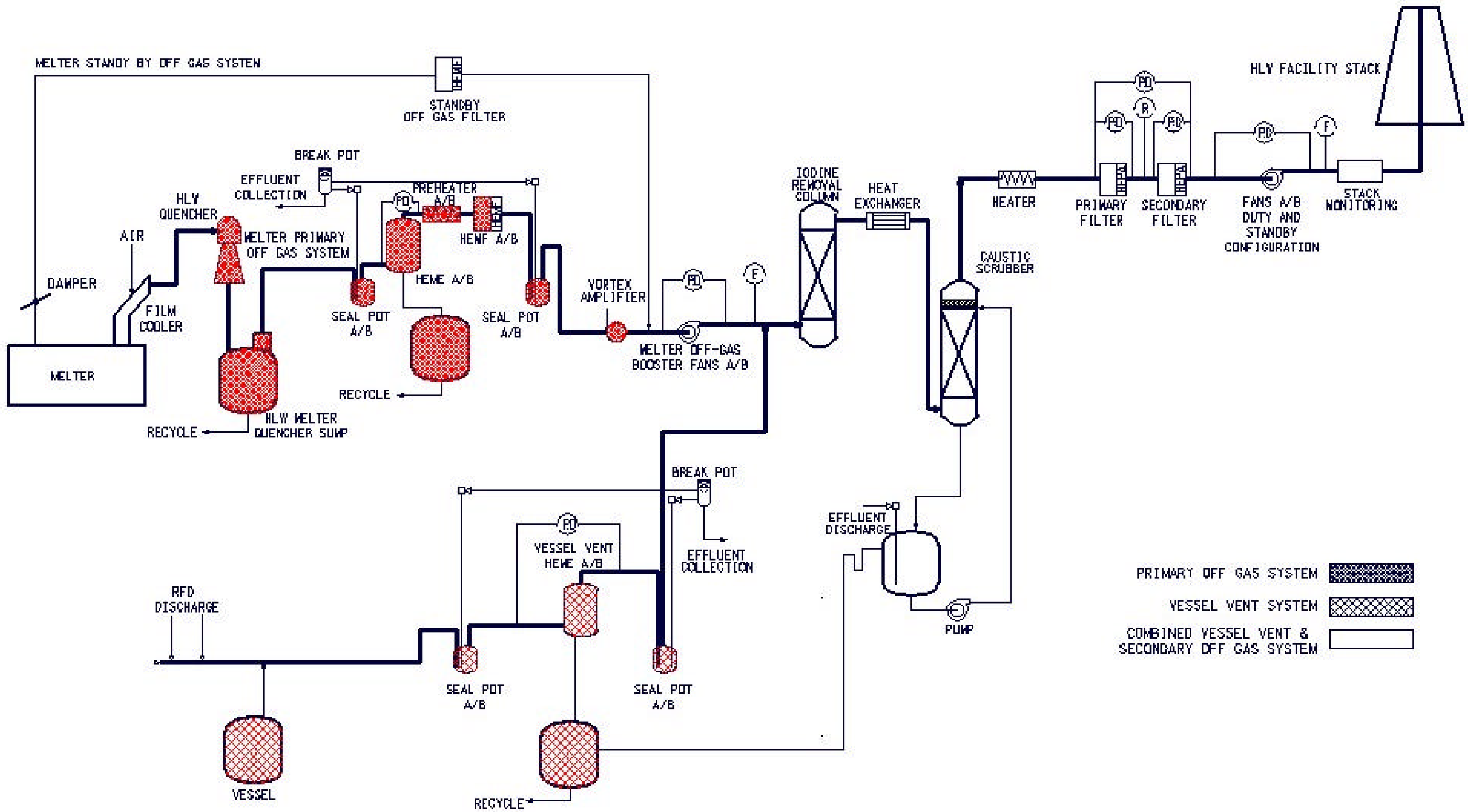

Table 2.2-7. Ventilation System – HLW Melter Primary Offgas System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of offgas cooling results in plugging of primary ventilation lines	Film cooler	Cool offgas Maintain melter depression Prevents buildup on downstream equipment	Temperature measurement and air flow control valve Testing and calibration of temperature/air flow control instrumentation
Loss of quenching results in high acidic offgas	Quencher	Remove acidic fumes from offgas	Vessel integrity Quencher is a Passive feature
	Quencher water pump	Maintain cooling water flow to the quencher	Redundant (2) standby/duty pumps powered by normal/alternate electrical power Automatic standby pump start on low flow Loss of more than one pump automatically shuts down melter feed and puts it in idle mode
	Quencher tank purge pump	Removes acidic water from quencher tank to maintain high decontamination factor of offgas fumes	Redundant (2) standby/duty pumps powered by normal/alternate electrical power Automatic standby pump start on low flow
	Quencher water Head Tank	Provides reliable source of make-up water for Quencher on loss of demineralized water	Vessel Integrity
HEME blockage (solids carryover & deposition)	HEME pressure differential instrumentation switch	Reveal HEME blockage	Alarm on differential pressure Trouble Alarm
Incorrect seal pot water level (inadvertent isolation) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity to areas of lower contamination	Level instrumentation switch	Alert operator of incorrect level in seal pot	Trouble Alarm Alarm on high level
	Seal Pot	Maintain ventilation flowpath	Seal pot depth to be sufficient to cater for water build up through condensation. Causing the sealing of the vent line
HEMF blockage due to high humidity	Air Reverse Pulse	Predetermined limits to preclude blockage	Trains Controls HEMF reverse air pulse to remove particulates
Pressure surges in melter (cause of unspecified potential damage)	Vortex amplifier	Eliminates excessive pressure fluctuations in the primary offgas system	Passive design verified during commissioning Reliability of motive air

Table 2.2-7. Ventilation System – HLW Melter Primary Offgas System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of melter vacuum or increase in pressure due to loss of ventilation	Booster fan	Maintain adequate depression and system flow	Multiple fans duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal Connected to combined Vessel Vent/Offgas system (main fans and HEPA)
	Power supply	Supply power	Normal electrical power (A and B trains)
Loss of melter depressurization due to primary path failure or melter pressure increase above primary path capacity resulting in loss of cascade ventilation principle and migration of activity from areas of higher contamination to areas of lower contamination potential	Standby off-gas system consisting of: Pipework Damper HEMF Melter high pressure switch	Provide alternate route to primary off-gas system stream	Reliability of the standby system is provided by the DSFs for the individual components addressed below
	Pipework	Maintain confinement and provide flowpath	Passive
	Damper	Open on high melter pressure	Self contained air solenoid Alarm on loss of service
	HEMF	Maintain flowpath	Passive Redundant with wash capability of offline unit
	Melter high pressure switch	Open standby exhaust system damper on high melter pressure	Trouble Alarm

Table 2.2-8. Ventilation System – LAW Melter Primary Offgas System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of offgas cooling results in plugging of primary ventilation lines	Film cooler	Cool offgas Maintain melter depression Prevents buildup on downstream equipment	Temperature measurement and air flow control valve Testing and calibration of temperature/air flow control instrumentation
Loss of quenching results in high acidic offgas	Quencher	Remove acidic fumes from offgas	Vessel integrity Quencher is a Passive feature
	Quencher water pump	Maintain cooling water flow to the quencher	Redundant (2) standby/duty pumps powered by normal/alternate electrical power Automatic standby pump start on low flow Loss of more than one pump automatically shuts down melter feed and puts it in idle mode
	Quencher tank purge pump	Removes acidic water from quencher tank to maintain high decontamination factor of offgas fumes	Redundant (2) standby/duty pumps powered by normal/alternate electrical power Automatic standby pump start on low flow
	Quencher water Head Tank	Provides reliable source of make-up water for Quencher on loss of demineralized water	Vessel Integrity
HEME blockage (solids carryover & deposition)	HEME pressure differential instrumentation switch	Reveal HEME blockage/degradation	See CE&I section
Incorrect seal pot water level (inadvertent isolation) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity to areas of lower contamination	Level instrumentation switch	Alert operator of incorrect level in seal pot	Trouble Alarm Alarm on high level
	Seal Pot	Maintain ventilation flowpath	Seal pot depth to be sufficient to cater for water build up through condensation. Causing the sealing of the vent line
HEMF blockage due to high humidity	Heaters	Maintain humidity to predetermined limits to preclude blockage	Redundant standby/duty heater trains Heater temperature monitor and controls HEMF reverse air pulse to remove particulates

Table 2.2-8. Ventilation System – LAW Melter Primary Offgas System

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Pressure surges in melter (cause of unspecified potential damage)	Vortex amplifier	Eliminates excessive pressure fluctuations in the primary offgas system	Passive design verified during commissioning. Reliability of motive air
Incorrect temperature of LAW SCR unit resulting in buildup of ammonium nitrate and potential explosion	SCR unit Temperature instrumentation	Prevent ammonium nitrate buildup Alert operator on high temperature	SCR designed to operate at high enough temperature to preclude ammonium nitrate formation (exothermic reaction) Trouble Alarm
High Nox emmissions due to loss of ammonia supply to the SCR or incorrect SCR temperature	NO_x monitor in stack	To monitor NO_x in off-gas stream	Trouble alarm UPS
	NO_x monitor power supply	Supply power to monitor	UPS
	NO_x CCR alarm	Provide indication of high NO_x to operators	UPS
Loss of melter depression leading to loss of primary confinement	Booster fan	Maintain adequate depression and system flow	Multiple fans duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal Connected to combined Vessel Vent/Offgas system (main fans and HEPA)
	Power supply	Supply power	Normal electrical power (A and B supplies)
Loss of melter depressurization due to primary path failure or melter pressure increase above primary path capacity resulting in loss of cascade ventilation principle and migration of activity from areas of higher contamination to areas of lower contamination potential	Standby off-gas system consisting of: Pipework Damper HEMF Melter high pressure switch	Provide alternate route to primary off-gas system stream	Reliability of the standby system is provided by the DSFs for the individual components addressed below
	Pipework	Maintain confinement and provide flowpath	Passive
	Damper	Open on high melter pressure	Self contained air solenoid Alarm on loss of service
	HEMF	Maintain flowpath	Passive Redundant with wash capability of offline unit
	Melter high pressure switch	Open damper on high pressure	Fail safe

Table 2.2-9. Vessel Ventilation- Combined Vessel Vent and Melter Offgas System (HLW or LAW)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Loss of Iodine removal capability in releases of airborne radioactivity exceeding allowable limits	Iodine absorber column (HLW system only)	Maintain flowpath and provide required DF for iodine	Vessel integrity Passive System
Fan failure resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Fans	Maintain negative pressure and flow in system	Multiple fans (2x100%) duty/standby Standby fan automatically starts on loss of duty fan 2 out of 3 fault signal -or- fan isolation damper closed Procedural controls for duty sharing
	Power supply for fans	Supply power to fans	Emergency electrical power
	Cascade trip instrumentation	Initiate ventilation system shutdown sequence on loss of Vessel vent extract fans	Overall system has diversity built in through the use of multiple inputs as shown below
	Low fan speed switch	Provide input to shutdown sequence instrumentation	Fan low speed alarm Fail safe on loss of power, loss of input/output signal
	Low fan flow switch	Provide input to shutdown sequence instrumentation	Fan low flow alarm Fail safe on loss of power or loss of input/output signal
	Fan low differential pressure switch	Provide input to shutdown sequence instrumentation	Fan differential pressure alarm Fail safe on loss of power or loss of input/output signal
	Fan damper closed proximity switch	Detect closure damper Provide input to standby fan auto start logic	Fail safe on loss of power or loss of input/output signal
	Logic circuitry	Shutdown C5 extract fan on 2 from 3 fault signal from vessel vent extract low speed, low flow, and low fan pressure differential -or- damper closed signal	Diversity (2 from 3 fault signal from C3 extract low speed, low flow, and low fan pressure differential) -or- damper closed signal Fail safe on loss of power or loss of input/output signal

Table 2.2-9. Vessel Ventilation- Combined Vessel Vent and Melter Offgas System (HLW or LAW)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Incorrect seal pot water level (inadvertent isolation) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity to areas of lower contamination	Level instrumentation switch	Alert operator of incorrect level in seal pot	Trouble Alarm Alarm on high level
	Seal Pot	Maintain ventilation flowpath	Seal pot depth to be sufficient to cater for water build up through condensation causing the sealing of the vent line
HEMF blockage due to high humidity	Heaters	Maintain humidity to predetermined limits to preclude blockage	Redundant standby/duty heater trains Heater temperature monitor and controls HEMF reverse air pulse to remove particulates
Heater failure (blockage of HEPA) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Heater	Control humidity	Redundant heaters
	Power supply to heater (supporting service)	Provide power to heater	Emergency electrical power
	Temperature indication and alarm instrumentation	Reveal heater failure (indication/alarm)	Fail safe on loss of power, loss of input/output signal UPS
Scrubber flooding (blockage) resulting in loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Overflow line	Prevent level from obstructing air flow path	Passive system tested during commissioning Overflow line sized to maximum makeup

Table 2.2-9. Vessel Ventilation- Combined Vessel Vent and Melter Offgas System (HLW or LAW)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
Mis-set dampers in system leading to the potential to contaminate workers during fan maintenance or loss of cascade ventilation principle and potential migration of airborne radioactivity from areas of higher contamination to areas of lower contamination	Dampers	Automatically isolate failed fan on standby start Not isolate duty fan during normal operation	Fail safe (closed, spring) Air solenoids are fail safe Internal air reservoir with sufficient capacity for short term loss of compressed air (typically about 8 hrs) Manual override
HEPA failure due to high differential pressure resulting in releases of airborne radioactivity exceeding allowable limits	HEPA filters	Provide required decontamination factor (DF) below discharge limits	Filters banked with sufficient capacity such that spare filter is available for online filter change purposes (not redundant capacity) Procedural controls to change filter train based on predetermined operating parameters (e.g. pressure, time, activity)
	HEPA filter differential pressure instrument switch	Provide local differential pressure indication	Simple static device Procedural controls to change filters at predetermined delta pressure value
HEPA failure due to heater failure (fire or loss of humidity control) resulting in releases of airborne radioactivity in excess of allowable limits	HEPA	Maintain integrity in the event of a heater malfunction	Glass paper HEPA Filter coated to withstand high water loading Passive feature (sufficient distance between heater and HEPA to preclude heat/fire damage)

Table 2.2-9. Vessel Ventilation- Combined Vessel Vent and Melter Offgas System (HLW or LAW)

Fault	Important to Safety SSCs	Safety Function	Design Safety Features
HEPA failure – Due to incorrect installation on changeout or filter breach resulting in releases in excess of allowable limits	Radiation monitor downstream of filters	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor downstream of both filter stages	Provide indication and alarm of excessive radiation in the discharge stream	UPS Trouble alarm
	Radiation monitor CCR/ICR alarm	Notify operator to initiate shutdown sequence	UPS Fail safe on loss of power, loss of input/output signal
	Isolation damper	Isolate exhaust stream	Motor operated with manual override Position indication
	HEPA filter differential pressure instrument switch	Provide indication of incorrectly installed or breached filter	Simple static device Procedural controls to troubleshoot filter on low differential pressure
	Efficiency test points	Allow testing to confirm efficiency of installed filters	Test locations are within C3 ventilated areas (any leakage will return to C3 ventilation system) Test connections have double isolation when not in use